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(54) Method of and apparatus for separating a medium into components of different particle masses in a vortex system

(57) A method of and apparatus for separating a medium into components of different particle masses by means of centrifugal force in equipment, e.g. cyclones, operating with turbulence free flow. The invention serves to reduce friction between a vortex and a chamber by removing part of a chamber wall from between parallel vortexes. The supporting action of a chamber wall is compensated for by colliding parallel, oppositely rotating vortexes with each other at angle of 0 to 90°. Adjacent to a separating vortex is a forced vortex rotating in opposite direction. Vortex separators can be built up into extensive systems with parallel vortexes positioned e.g. peripherally or in a regular square net. Thus, separating vortexes and forced vortexes alternate in such a system.

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Fig. 1

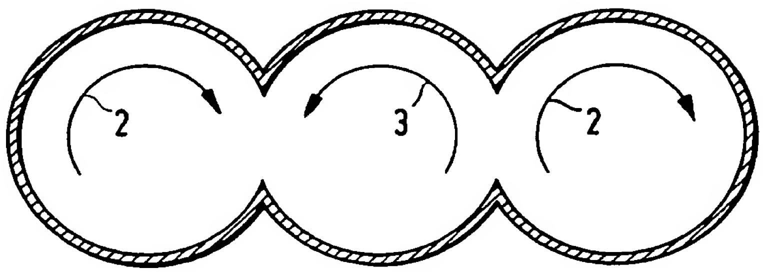
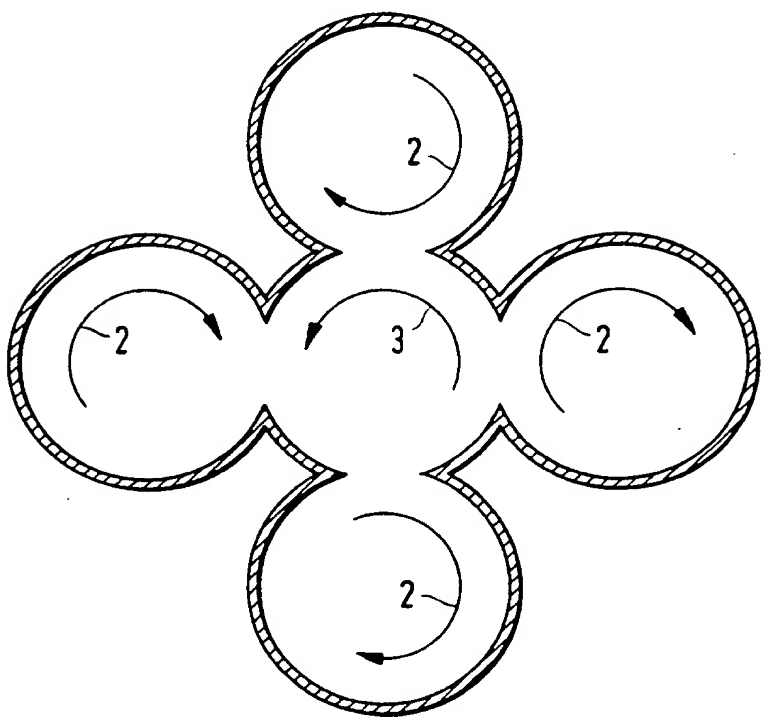


Fig. 2



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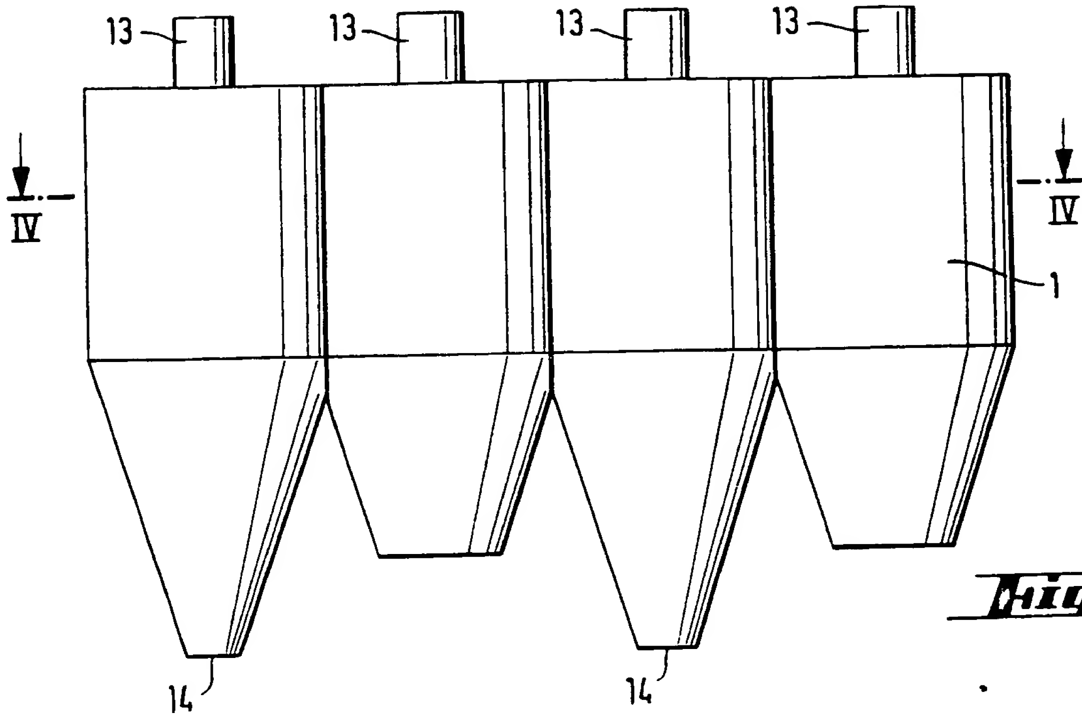
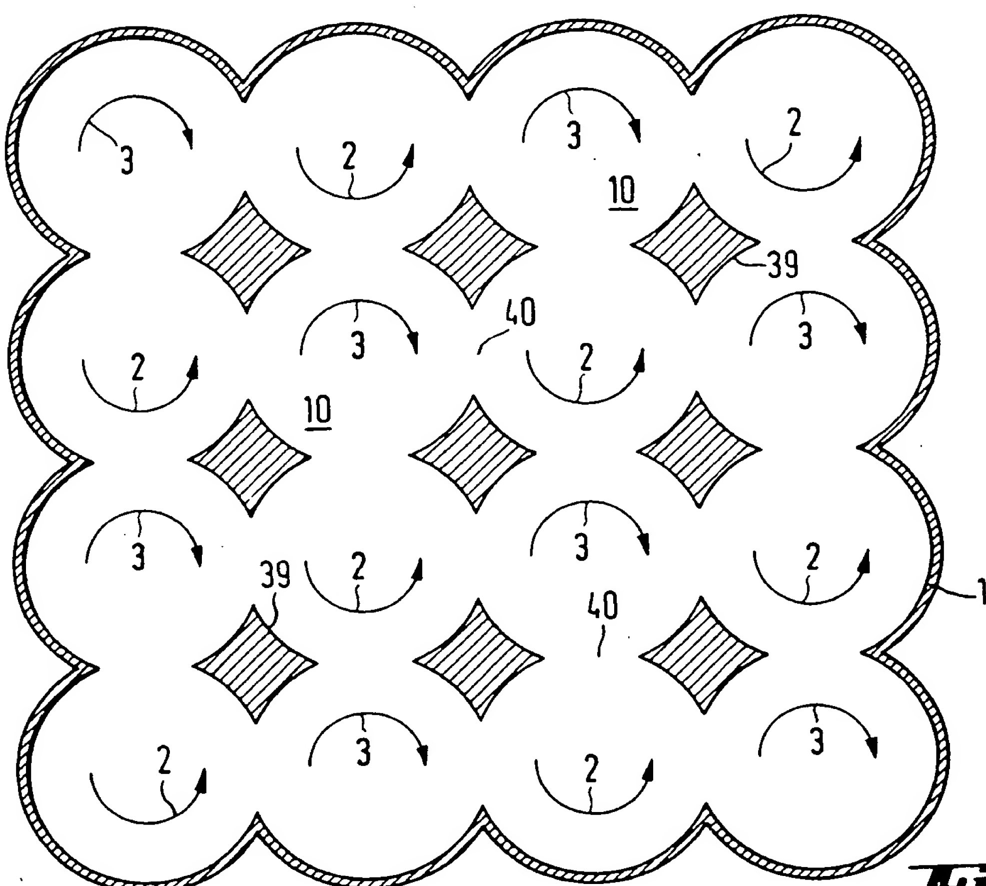


Fig. 3



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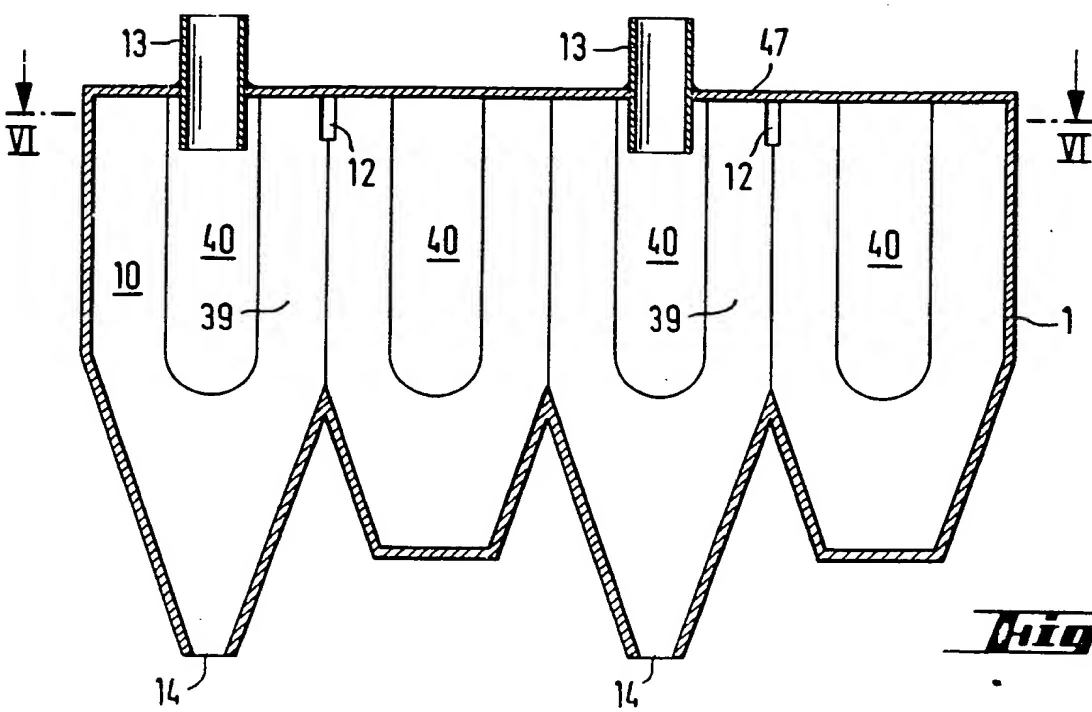
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47
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39
1
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14

Fig. 5

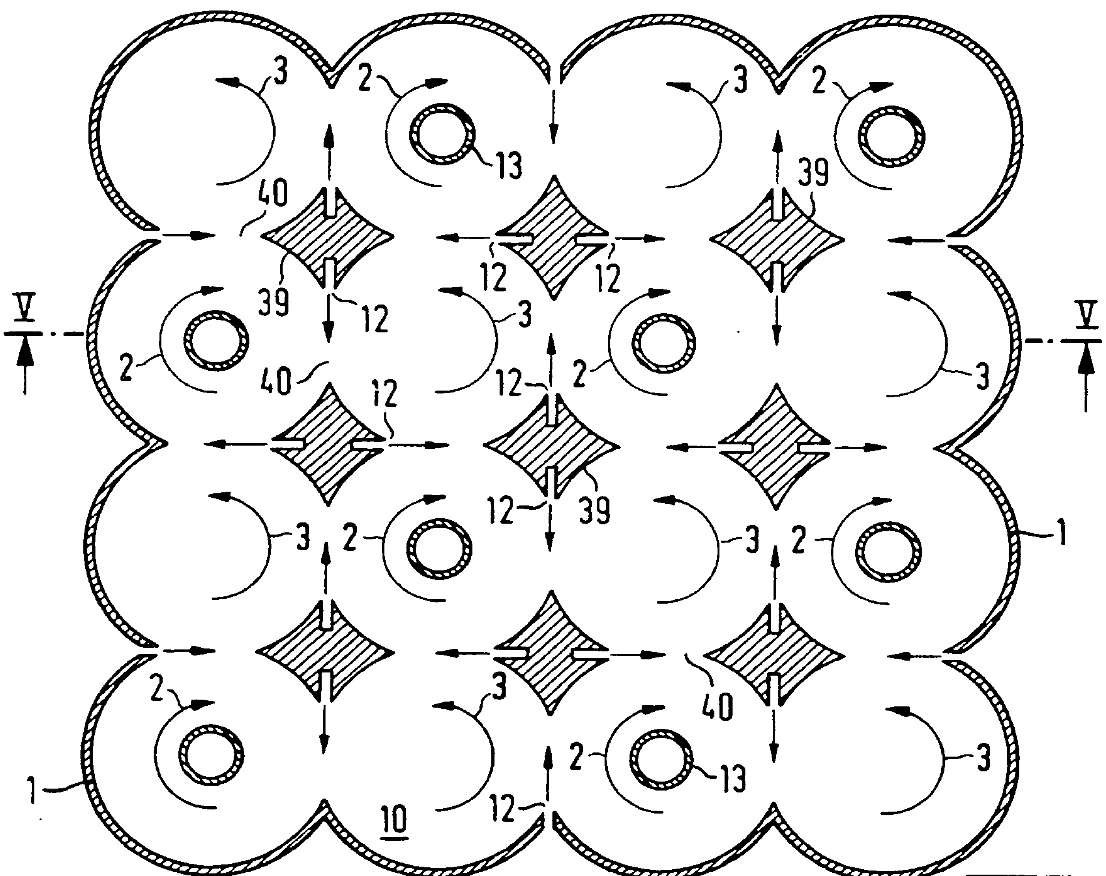
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Fig. 6

Fig. 7

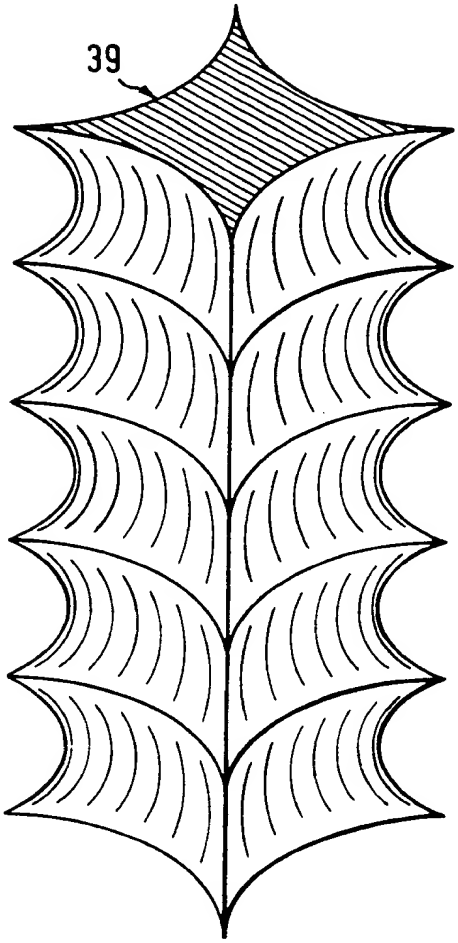


Fig. 8

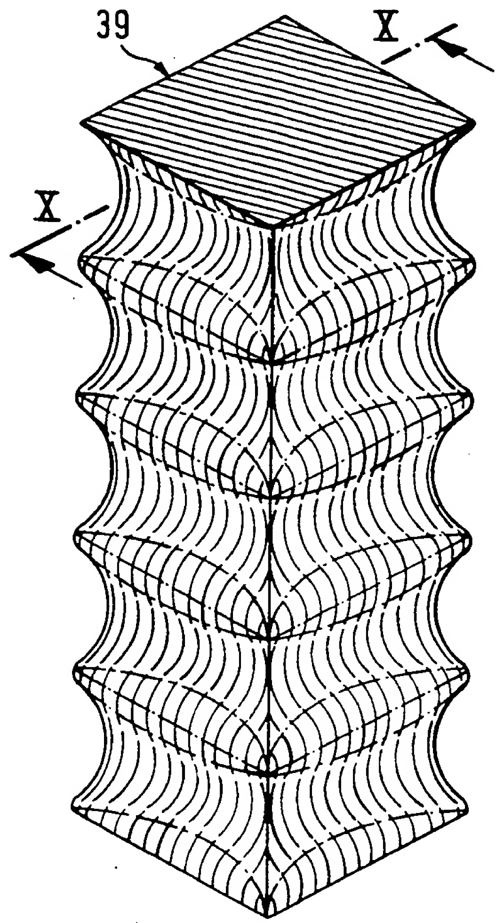


Fig. 9

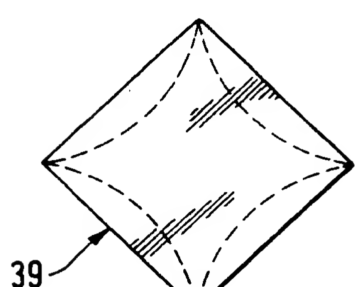


Fig. 10

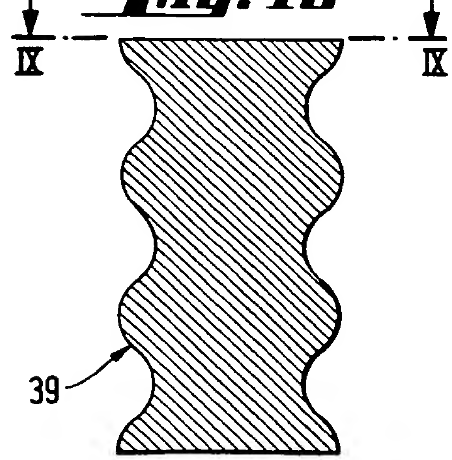
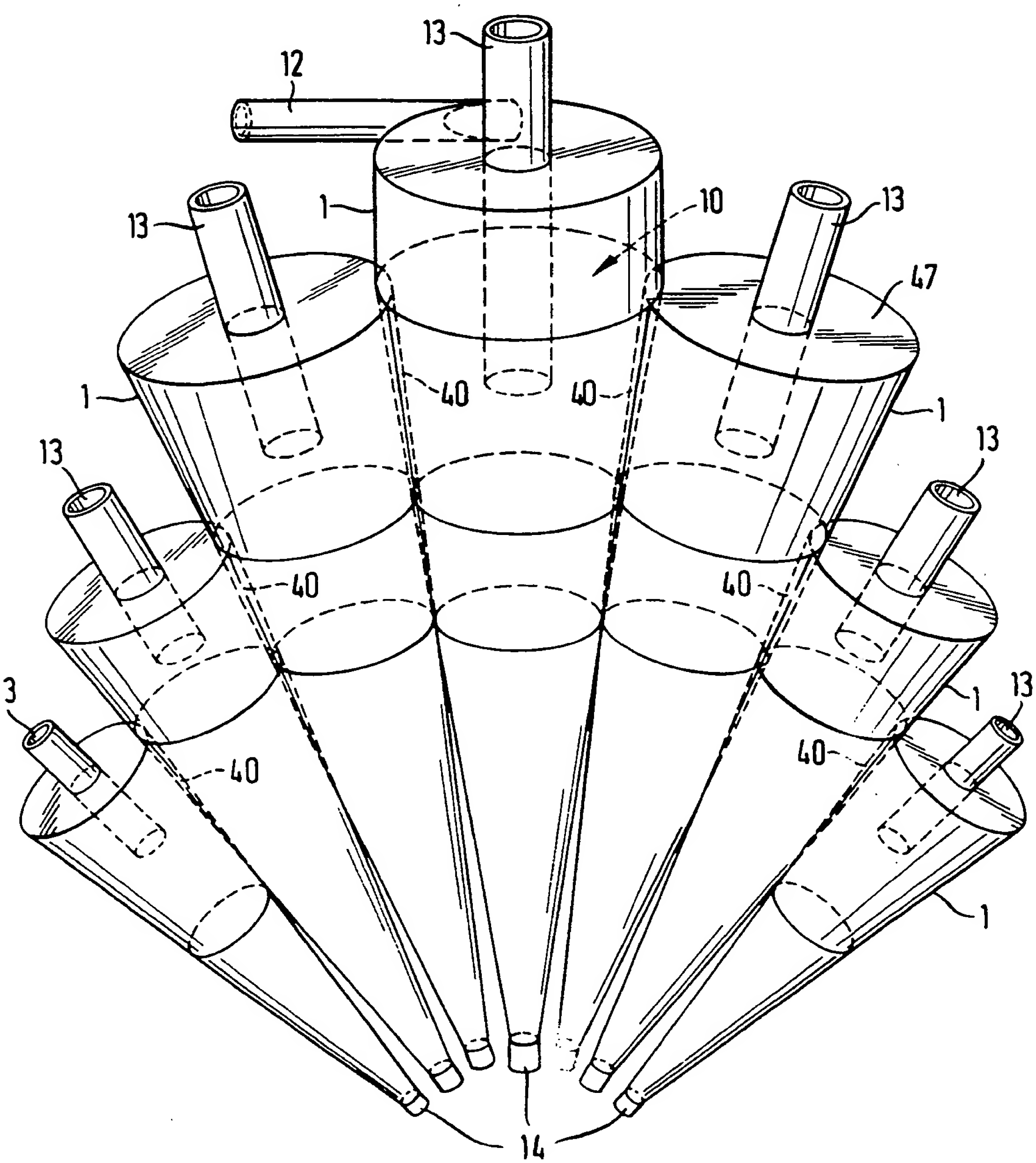


Fig. 14



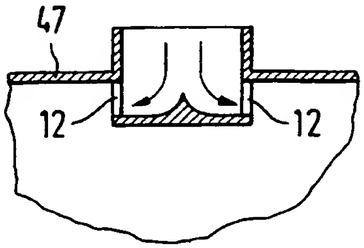


Fig. 11

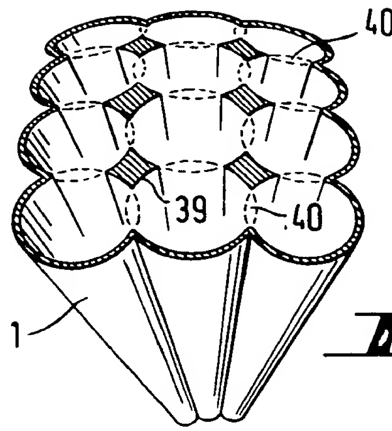


Fig. 12

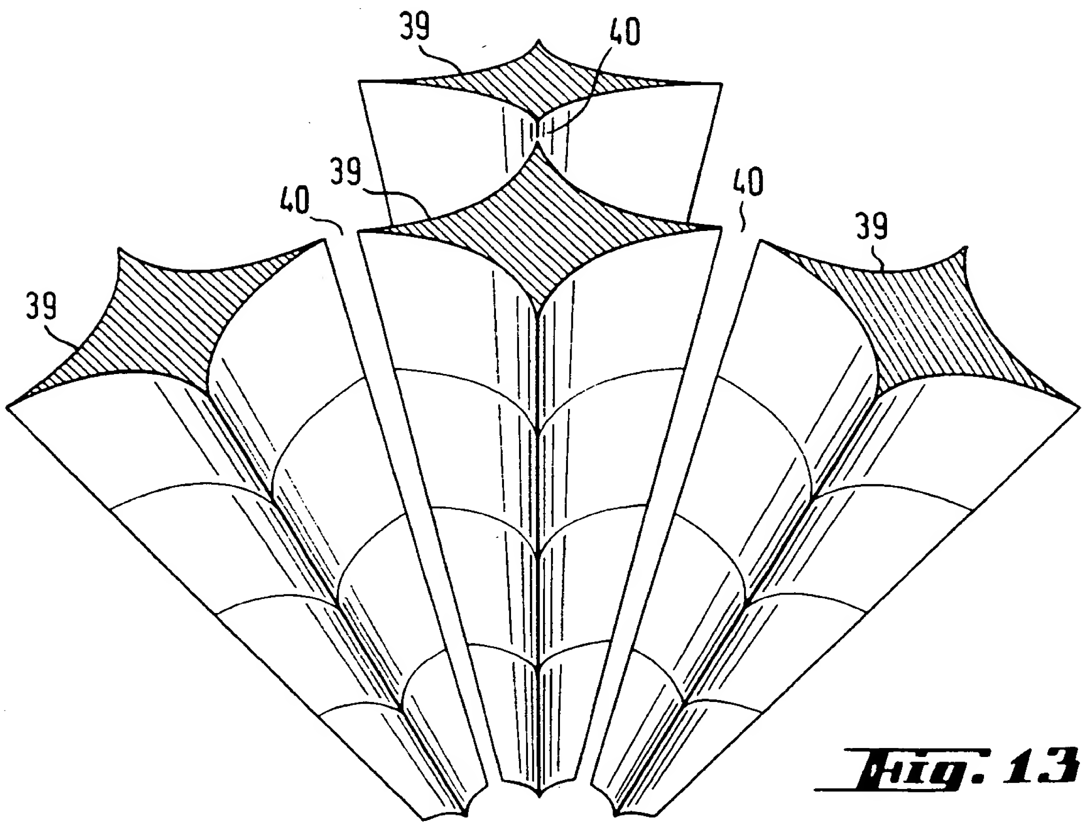


Fig. 13

SPECIFICATION

Method of and apparatus for separating a medium into components of different particle masses in a vortex system

This invention relates to a method of and apparatus for separating a medium into components of different particle masses by means of centrifugal force in turbulent flow-operated devices, e.g., in cyclones, in a manner that particles having a major mass concentrate during the rotation in the outer portions of a separating vortex and particles having a minor mass concentrate in those parts of a separating vortex which are close to the centre of rotation.

The term "medium", as used hereinafter, is intended to cover powdered and fibrous flowing solid substances, flowing liquids, liquid drops as well as mixtures thereof. Accordingly, the term "particle" is intended to cover solid particles, liquid drops, liquid molecules, gas molecules or gas atoms. The term "separation chamber" is intended to cover various turbulence chambers as well as flow pipes and flow chambers in which the separation is effected by means of contrifugal force.

Recognized in flowdynamics is free turbulent flow, wherein tangential velocity V is obtained by means of the radius of rotation r from formula.

$$V = k \, . \, r^{-1}$$

Hence, pressure in central parts of a vortex is lower than in outer portions.

In practice, the tangential velocity in vortex separators is slightly lower due to the action of attrition occurring in a vortex. In commercially available vortex separators, the tangential velocity is obtained in a separating vortex from formula.

$$(2) \qquad V = k \, r^{n} \qquad -1 < n < 0$$

Here, also pressure in the middle of a vortex is lower than in the margins. In a separating vortex, pressure energy turns into kinetic energy. In this specification, term "separating vortex" refers to a vortex of formula (2) whose pressure is substantially lower in the middle than in the margins. If the shape of a vortex is other than circular, formula (2) can only be applied approximately.

Also known in flow dynamics is a forced vortex, wherein tangential velocity is obtained from formula.

$$(3) \qquad V = k \, r$$

Angular speed in various sections of a vortex is thus constant. In the middle of a forced vortex, the pressure is not essentially lower than in marginal sections, since there is no conversion of pressure energy into kinetic energy. In this specification, term "forced vortex" means a vortex according to formula (3) or close to it. If such vortex differs from circular, formula (3) can only be applied approximately. A forced vortex is generated by the action of external motion.

A plurality of vortex separator designs such as cyclones are known, wherein the vortex is confined by cylindrical and conical surfaces. Generally a vortex chamber has smooth surfaces and the wall of a chamber is continuous in the direction of turbulent flow. For example, multicyclones have been built by positioning such independently operated vortex separators parallel to each other. An example of this is set out in US Patent 3 747 306. In addition, several Patent publications disclose vortex separators, wherein two vortexes are tangentially in contact with each other permitting the transition of particles of a certain size tangentially from one vortex to the other.

Finnish Patent application no. 813387 discloses a method, wherein two or more parallel positioned separating vortexes are pairwise and laterally contacted with each other.

A drawback in the prior art vortex separators is that centrifugal force urges a medium vortex to be separated against the external bounding surfaces. Thus, friction decelerates the movement of a vortex and causes turbulence in the vicinity of the walls. Friction and the resulting turbulence create considerable energy losses. Due to the decelerated speed of rotation, centrifugal force and thus separating capacity are decreased in the outer periphery, which is the most important zone for the separation. In addition, said turbulence remixes some of the separation already effected. The prior art multicyclones require a lot of space and are heavy and bulky in construction. Due to the losses caused by friction, it is very difficult to reach high swirl velocities with presently known vortex or top separators.

In Patent Application No. 813387, the wall friction has been decreased but the violent collision of the vortexes partially cuts down the beneficial effect as for the consumption of energy.

An object of this invention is to alleviate the above drawbacks.

According to the present invention there is provided a method of separating a medium into components of different particle masses by means of centrifugal force in free turbulent flow operated equipment wnerein a separating vortex and a forced vortex are pairwise laterally contacted with each other so that they collide with each other at an angle of 0 to 90° while rotating in opposite directions, so that particles having a major mass are concentrated during the rotating motion in the outer portions of the vortexes and particles having a

minor mass are concentrated in those parts of the vortexes which are closer to the centres of rotation there of.

The present invention also provides apparatus for carrying out the method, including turbulence or vortex chambers, adjacent pairs thereof lying partially within each other to provide a collision area with the colliding parallel vortexes rotating in opposite directions.

The invention will now be illustrated by the following drawings.

Figure 1 is a cross section of a vortex system of the invention, with one forced vortex between two separating vortexes.

Figure 2 is a cross section of a vortex system of the invention, with one forced vortex between four separating vortexes.

Figure 3 is a side view of a separator system of the invention.

Figure 4 is a section along IV–IV in Fig. 3.

Figure 5 is an axial section of a separator system of the invention.

Figure 6 is a section along line VI–VI Fig. 5.

Figure 7 is an axonometric view of one embodiment of a flow divider.

Figure 8 is an axonometric view of another embodiment of a flow divider.

Figure 9 shows the cross-sectional variation of a flow divider in Fig. 8.

Figure 10 is a section along the axis of rotation along line X–X in Fig. 8.

Figure 11 is a side view of one embodiment of a tangential supply in Fig. 6.

Figure 12 is a perspective view of a separator system of the invention in which the vortexes are conical.

Figure 13 is an axonometric view of flow dividers in a separator system in which the vortexes are conical.

Figure 14 is an axonometric view of one separator system of the invention, with the vortexes staggered in axial direction.

The essential subject matter of this invention is to reduce the contact between a separating vortex and a surface that confines said vortex on the outer periphery, the drawbacks caused by such contact being eliminated. For this end part of the surface which confines or limits the vortex on the outer periphery is removed. The support action of the surface urging the vortex inwards is compensated for by colliding a separating vortex and a forced vortex with each other during their rotation, whereby said vortexes push each other. The vortexes colliding with each other at a small angle do not create turbulence and there is hardly any friction therebetween providing that the rotational speeds are equal. A separating vortex will be shaped nearly circular due to its stronger centrifugal force with a subsequent reduction of an energy loss resulting from an angular configuration.

The appended figures show by way of example some embodiments of the invention as well as illustrate the mode of operation of the invention. In reality, a plurality of various embodiments are conceivable for this invention. The shapes and dimensions of the equipment of the invention are chosen according to a given end use. Experimental researches and theoretical studies can be used for assistance.

The components illustrated in the figures are termed as follows:–

1. a surface which confines the vortex on the side of outer periphery
2. the travelling path of a separating vortex in general outline
3. the travelling path of a forced vortex in general outline.
10. a vortex chamber for separating vortex or forced vortex
12. a tangential inlet pipe through which particles to be separated enter a separation space.
13. an axial outlet pipe for particles having a minor mass after the separation
14. an axial outlet pipe for particles having a major mass after the separation
39. a flow divider for separating various vortexes from each other
40. a collision zone where a separating vortex and a forced vortex collide with each other
47. a lid for the turbulence chamber

Figs. 1 and 2 show separating vortexes 2, which are set in high-speed rotation, spin a forced vortex 3 therebetween. The forced vortex 3 receives its energy from the separating vortexes 2 around it. The forced vortex 3 functions like a bearing between said separating vortexes 2 without actively participating in the acual separation. In principle, the material in the forced vortex 3 can run its orbit almost continuously. In practice, also the material composition of the forced vortex 3 gradually changes. It is primarily the heavier component of a mixture to be separated that tends to accumulate in said forced vortex 3. In order to discharge it, it is possible to arrange an individual outlet at the forced vortex therefor. The lid and bottom of a forced vortex are generally closed but their configuration can be e.g. domed or cupped.

The side view of Fig. 3 illustrates one vortex system according to the invention with 4 × 4 vortexes coupled to each other. Supply means have not been shown in the figures. The supply or feed of a medium to be separated can be effected axially or tangentially. In the case shown in Fig. 3, the fractions to be separated discharge in axial direction but tangential discharge arrangements are also possible. The supply or feed of said separating vortexes 2 can also be effected via forced vortexes 3.

The sectional illustration of a vortex system shown in Fig. 4 discloses that the individual vortex or turbulence chambers 10 are of equal

size. In this case, the flow dividers 39 consist of four smooth sections of a cylindrical surface. The size of flow dividers 39 can vary considerably. Even extremely small flow dividers 39 are possible.

The sectional view of Fig. 5 shows one vortex system fitted with tangential inlets 12 which are disposed between a separating vortex 2 and a forced vortex 3.

Fig. 6 shows the corresponding tangential inlets 12 from above.

Fig. 7 shows a flow divider 39 which in the flow directions of said vortexes is provided with channel-shaped grooves and sharp ribs therebetween. By virtue of such a shape it is possible to modify the shape of an axial section of vortex 2 at various stages of the rotation. Within the collision area 40 of individual vortexes 2 and 3, the interface of said vortexes is in axial direction linear. As the particles arrive at a vortex divider 39 shown in Fig. 7, said particles are forced to partially move also in axial direction. Thus, the particles having different masses are more easily capable of passing by each other in the desired directions of separation. As for a flow divider 39, just the surface facing a separating vortex 2 can be made channel-shaped while the portion facing a forced vortex 3 is smooth.

In the type of a flow divider 39 set out in Fig. 8, 9 and 10, the axial section is wave-shaped. Between the wave-shaped ridges there are recesses into which vortexes 2 and 3 are urged. The regular shaping of a vortex 2 in axial and radial direction improves the separation.

Fig. 11 shows a detail of one possibility of effecting a tangential inlet 12 the case illustrated in Fig. 5 and 6.

Figs. 12 and 13 show one embodiment of arranging frusto conical vortex chambers. The width of a collision area 40 can be chosen as desired. Flow dividers 39 can be flat conical faces or they be made wavy or corrugated in the travel direction of vortex 2 or grooved in axial direction.

Fig. 14 shows one vortex system of the invention, wherein vortexes are staggered in axial direction. The supply of a medium to be separated is effected into the top central vortex from which some of the particles can pass laterally into other vortexes disposed in lower positions.

CLAIMS

1. A method of separating a medium into components of different particle means by means of centrifugal force in free turbulent flow operated equipment wherein a separating vortex and a forced vortex are pairwise laterally contacted with each other, so that they collide with each other at an angle of 0 to 90° while rotating in opposite directions, so that particles having a major mass are concentrated during the rotating motion in the outer portions of the vortexes and particles having a minor mass are concentrated in those parts of the vortexes which are closer to the centres of rotation thereof.

2. A method as set forth in claim 1, wherein a plurality of said separating and forced vortexes make up a vortex system in which the centres of rotation of said vortexes build a regular square net as seen in axial direction.

3. A method as set forth in claim 1, utilising a vortex system in which said forced vortex is peripherally surrounded by a plurality of said separating vortexes.

4. A method as set forth in claim 1, utilising a vortex system in which said separating vortex is peripherally surrounded by a plurality of forced vortexes.

5. An apparatus for carrying out the method as set forth in any of the claims 1–4, including turbulence or vortex chambers, adjacent pairs thereof lying partially within each other to provide a collision area with the colliding parallel vortexes rotating in opposite directions.

6. Apparatus as set forth in claim 5, wherein supply of a medium to be separated is effected into the collision area between said vortex chambers.

7. Apparatus as set forth in claim 5 or 6 wherein said vortex chambers are positioned in a regular square net parallel to each other.

8. Apparatus as set forth in claim 5 or 6 wherein one vortex chamber is peripherally surrounded by other vortex chambers.

9. Apparatus as set forth in any of the claims 5–7, wherein between four parallel vortex chambers there is a flow divider for four-branched cross-section.

10. Apparatus as set forth in claim 9, wherein the flow divider is grooved in the travel direction of a separating vortex.

11. Apparatus as set forth in claim 9, wherein the flow divider is corrugated in the travel direction of a separating vortex.

12. Apparatus for effecting a method as set forth in claim 3 or 4, the adjacent vortex chambers are staggered in the axial direction.

13. Apparatus as set forth in any one of claims 5 to 12 wherein the vortex chambers are frusto-conical.

14. Apparatus for separating a medium into components of different particle masses by means of centrifugal force, substantially as described herein with reference to and as illustrated in Fig. 1, or Fig. 2, or Figs. 3 and 4, or Figs. 5 and 6; or any of these Figures as modified by any one of Figs. 7 to 11; or Fig. 12 or Fig. 13 or Fig. 14 of the accompanying drawings.

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